

(12) **United States Patent**
Wang et al.

(10) **Patent No.:** US 6,925,357 B2
(45) **Date of Patent:** Aug. 2, 2005

(54) **MEDICAL TELE-ROBOTIC SYSTEM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 258 days.

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(21) Appl. No.: **10/206,457**

(22) Filed: **Jul. 25, 2002**

(65) **Prior Publication Data**

US 2004/0019406 A1 Jan. 29, 2004

(51) **Int. Cl.**⁷ **G06F 19/00**

(52) **U.S. Cl.** **700/245**; 700/246; 700/250;
700/254; 700/260; 700/261; 700/262; 318/568.12;
901/1; 901/2; 702/188

(58) **Field of Search** 700/245-246,
700/250, 254, 260-262, 253, 302; 318/568.12,
568.15, 568.11, 568.17, 567; 901/1, 2,
8.1, 8.6; 702/188; 340/870.17, 870.24;
53/501; 701/23, 1, 36; 600/590

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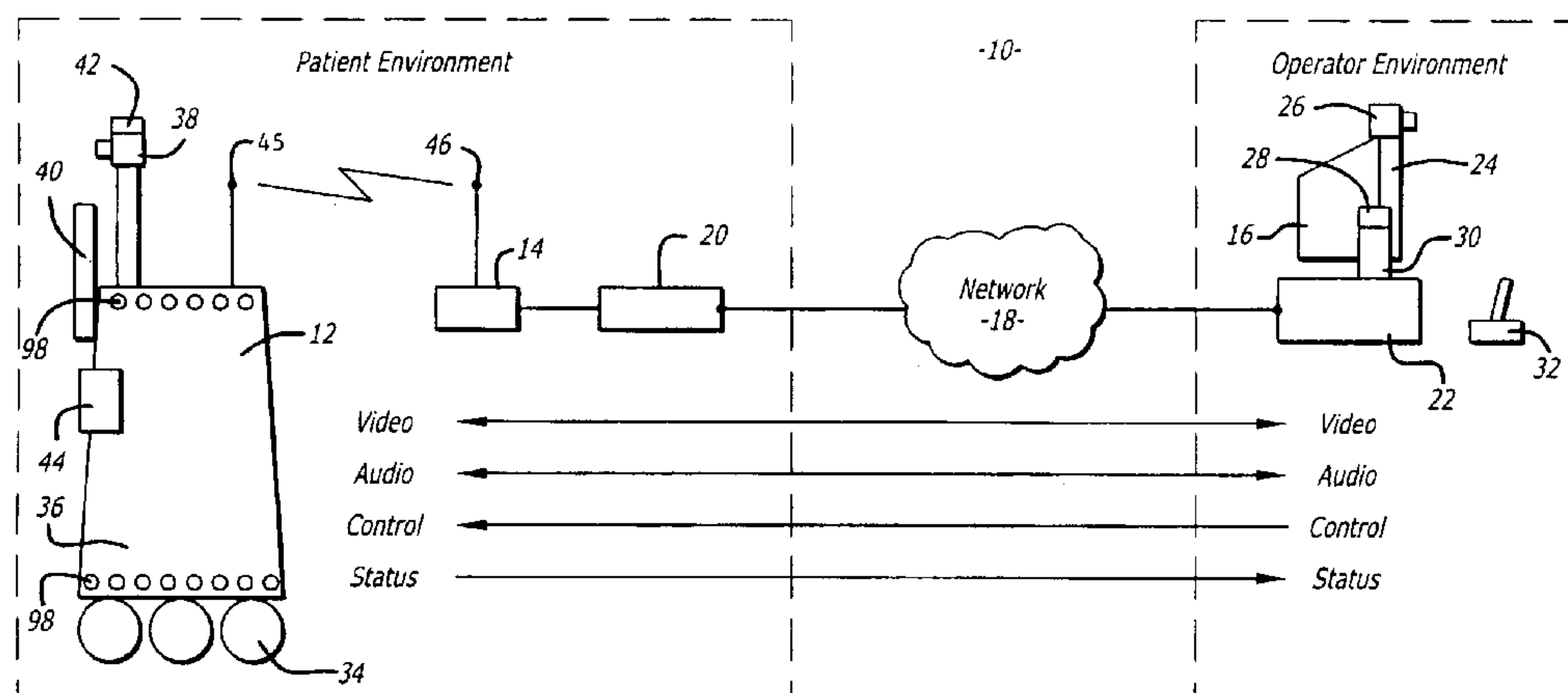
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(57) **ABSTRACT**

A robotic system that includes a remote controlled robot. The robot may include a camera, a monitor and a holonomic platform all attached to a robot housing. The robot may be controlled by a remote control station that also has a camera and a monitor. The remote control station may be linked to a base station that is wirelessly coupled to the robot. The cameras and monitors allow a care giver at the remote location to monitor and care for a patient through the robot. The holonomic platform allows the robot to move about a home or facility to locate and/or follow a patient.

78 Claims, 11 Drawing Sheets



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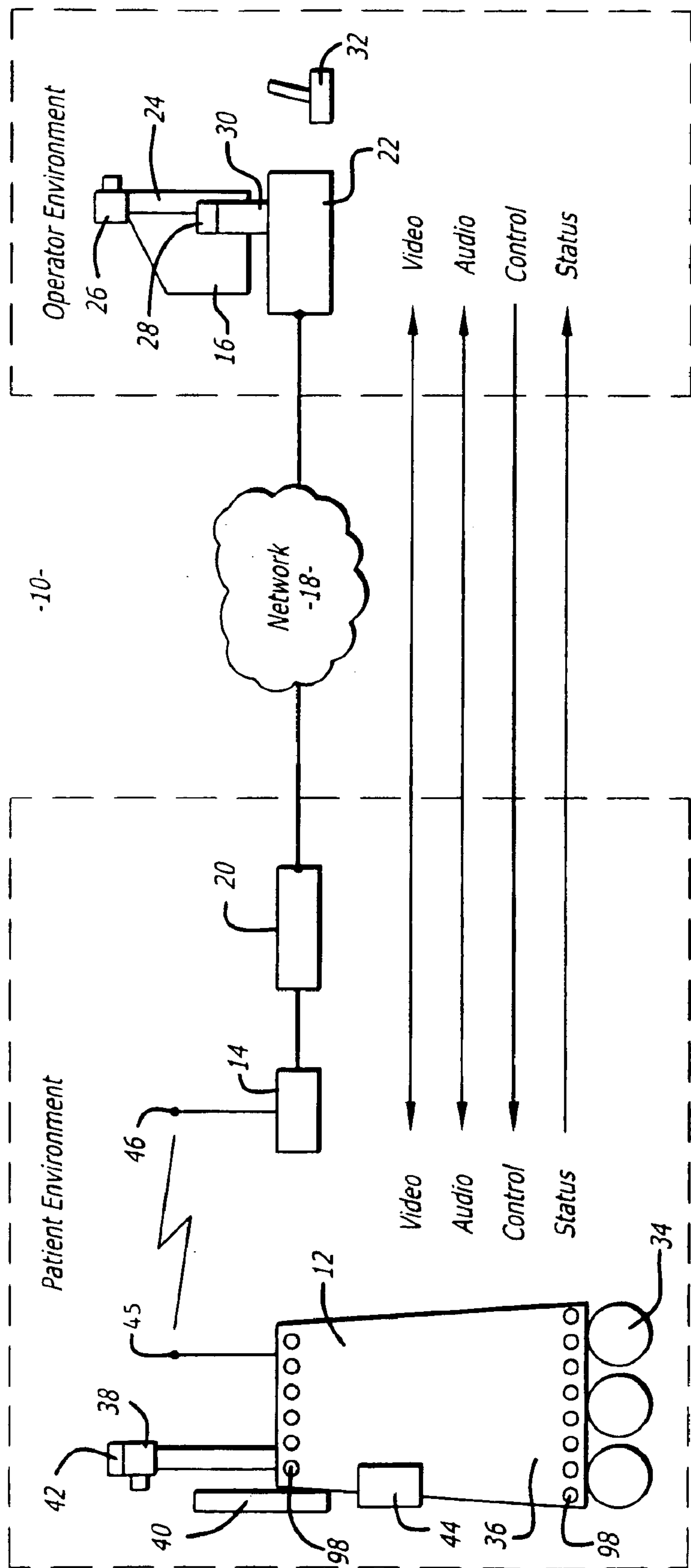
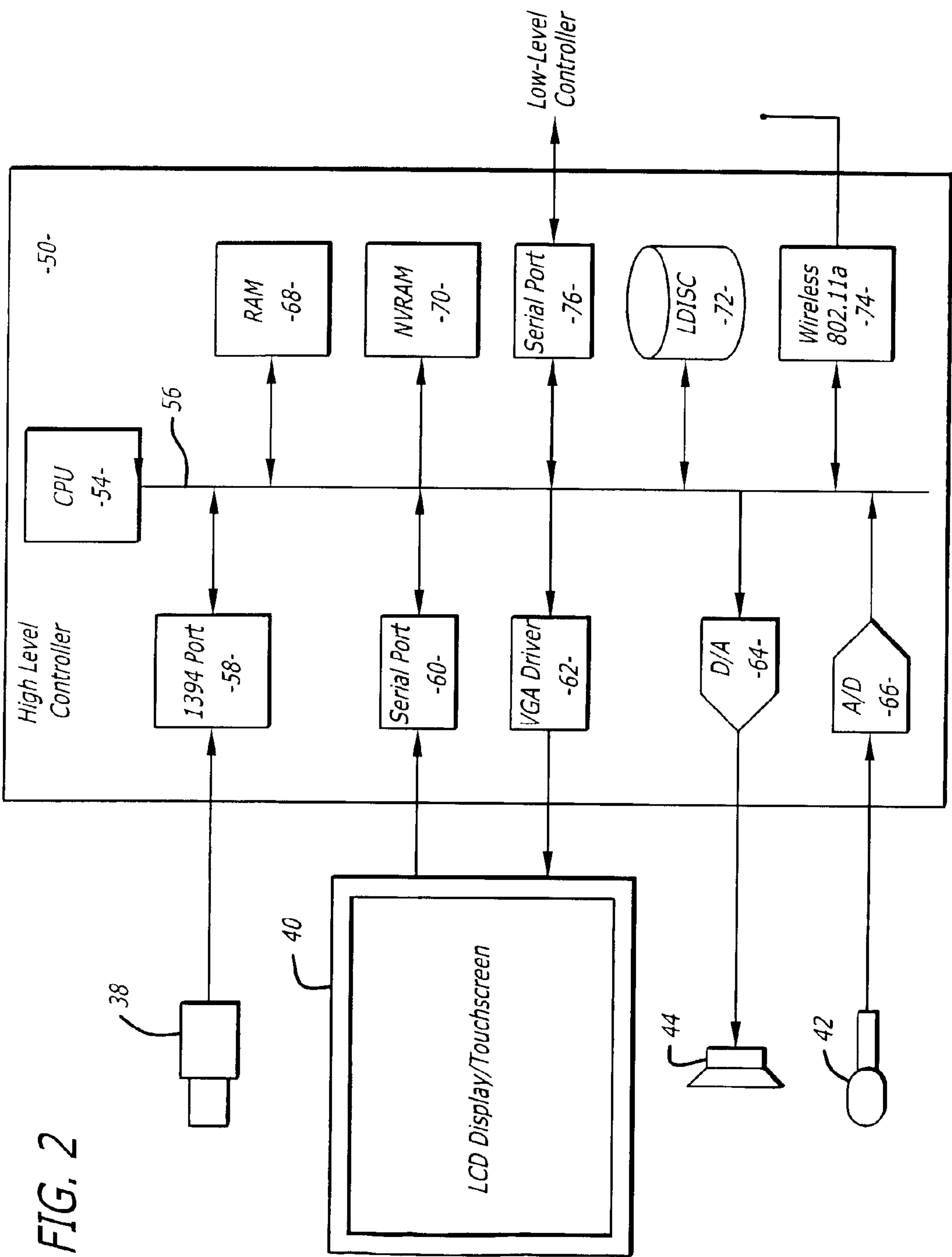


FIG. 1



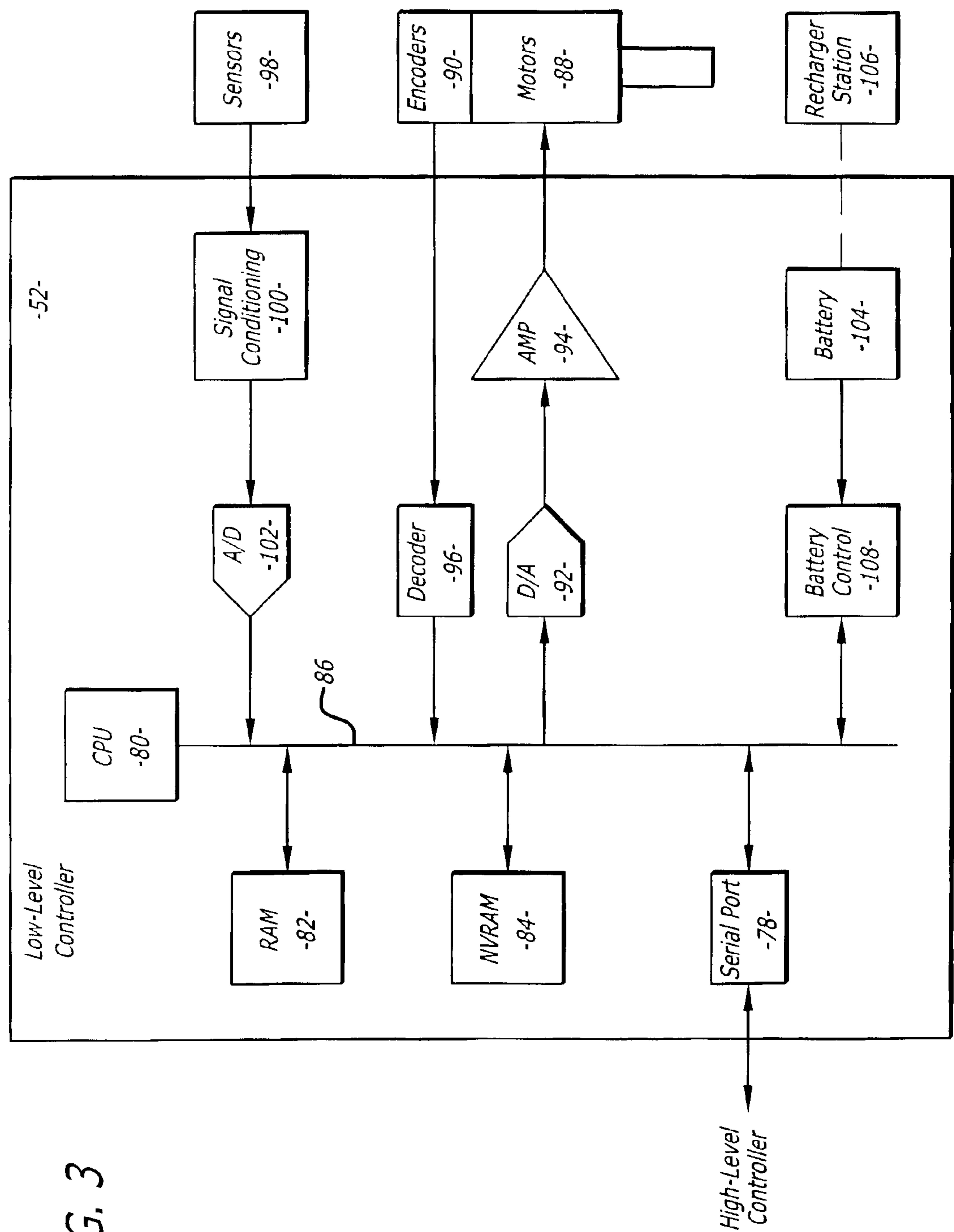


FIG. 3

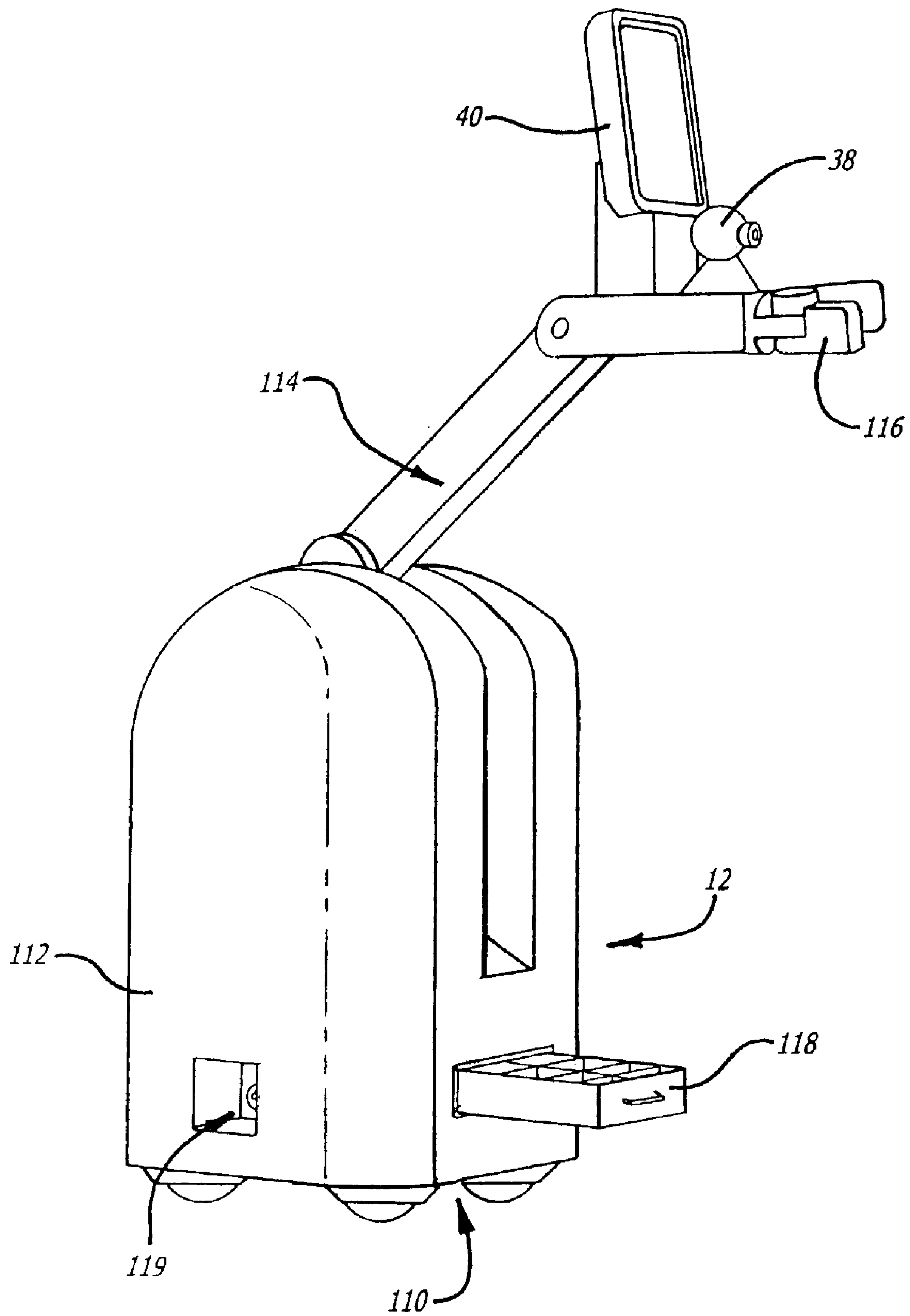
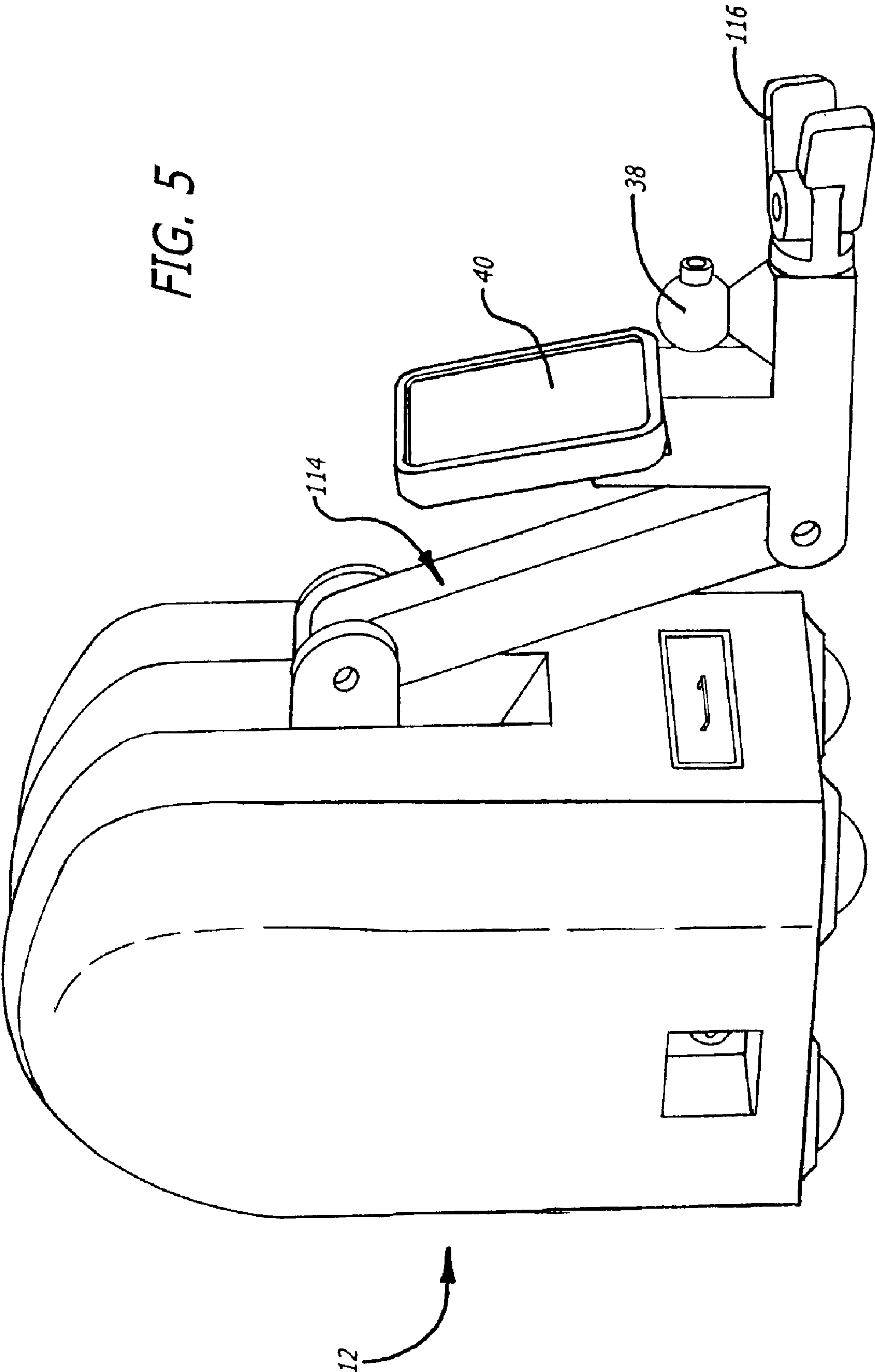
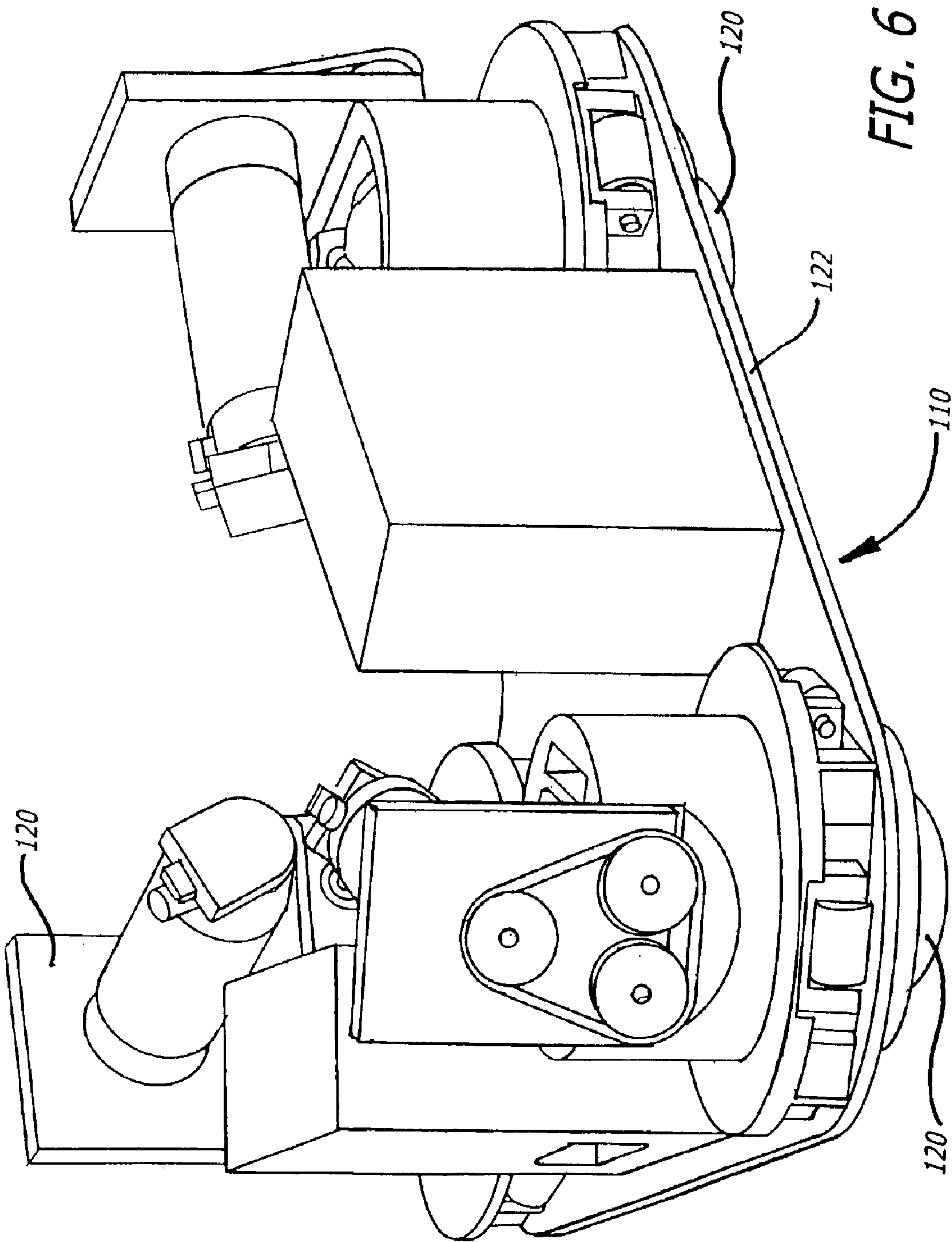


FIG. 4

FIG. 5





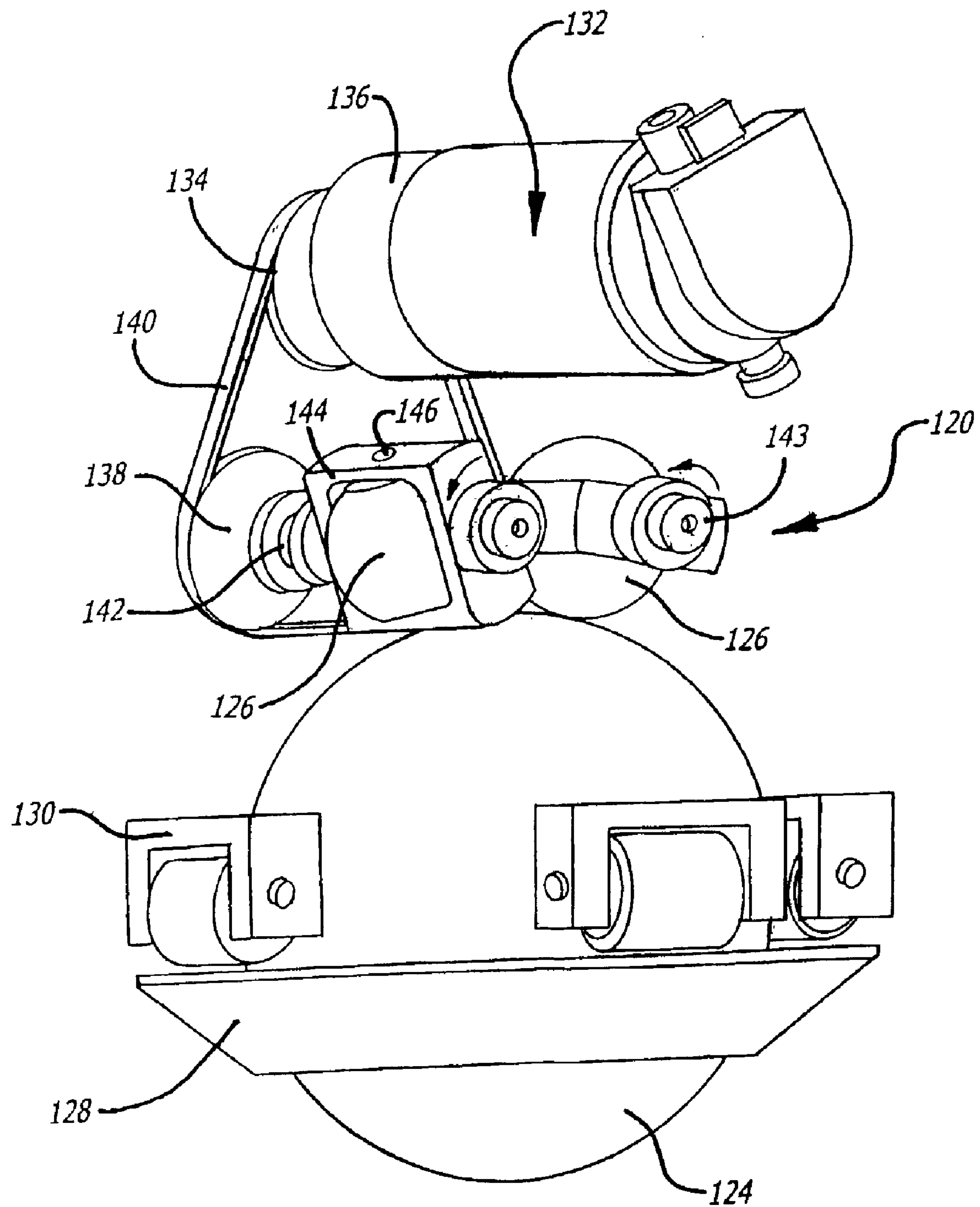
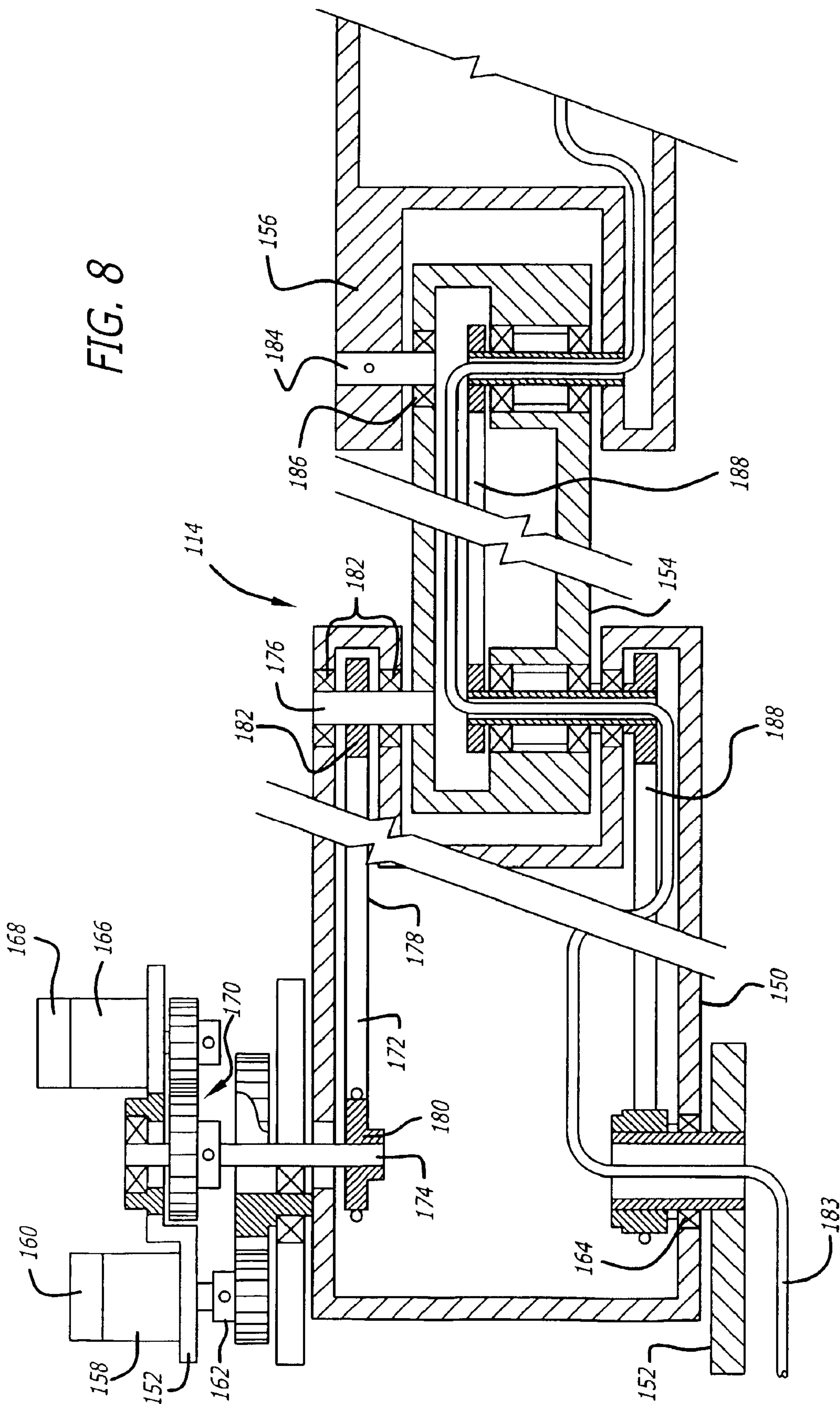
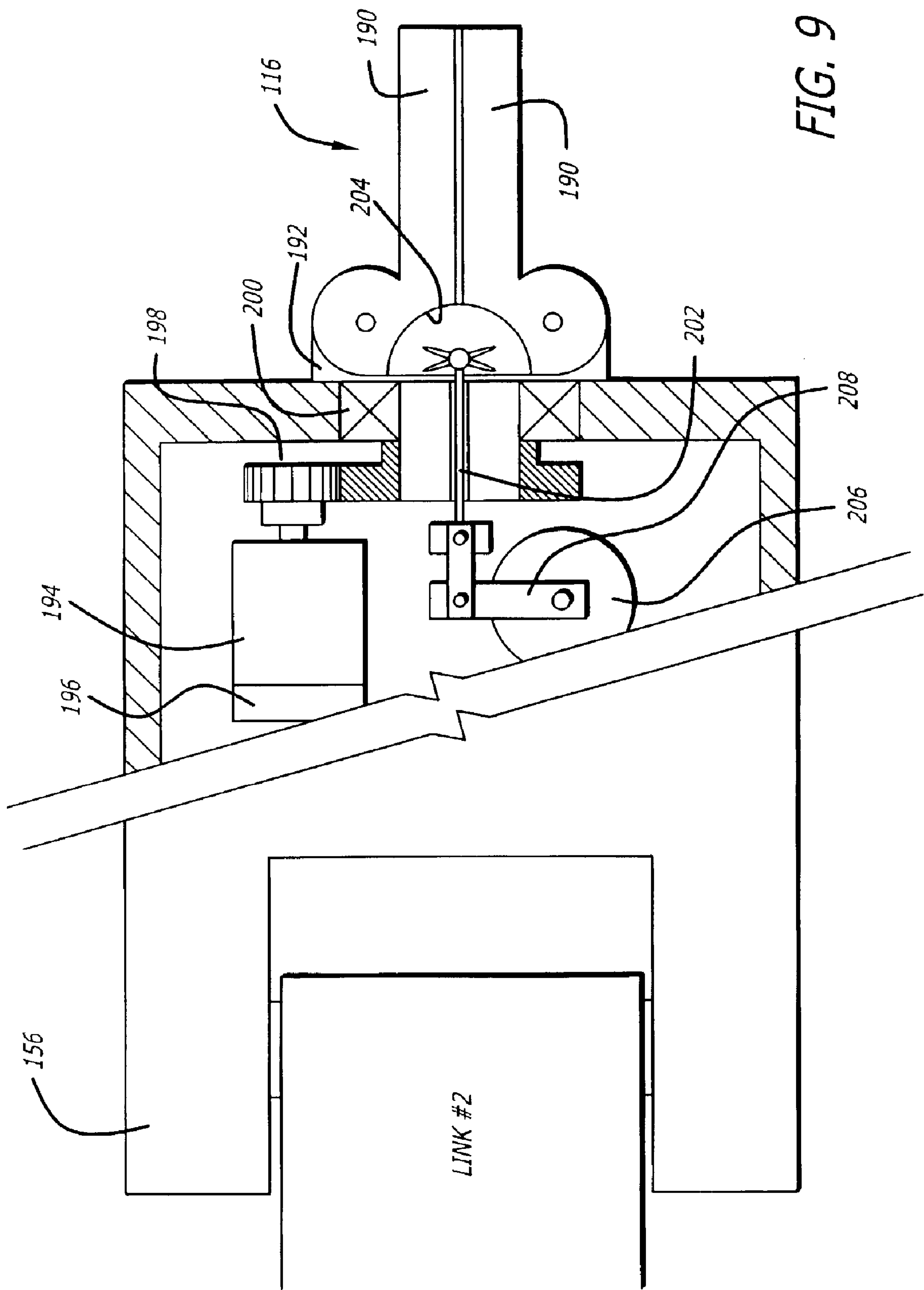


FIG. 7





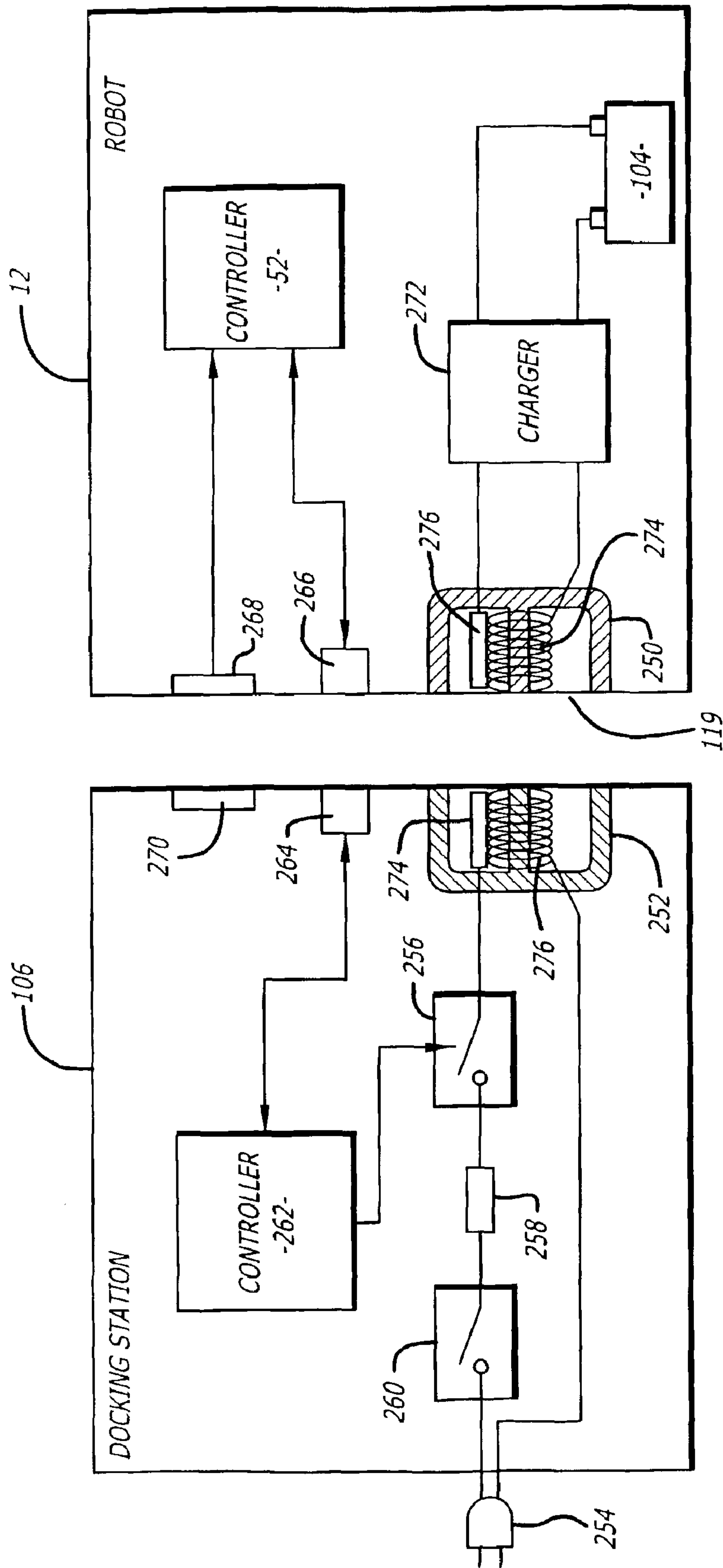
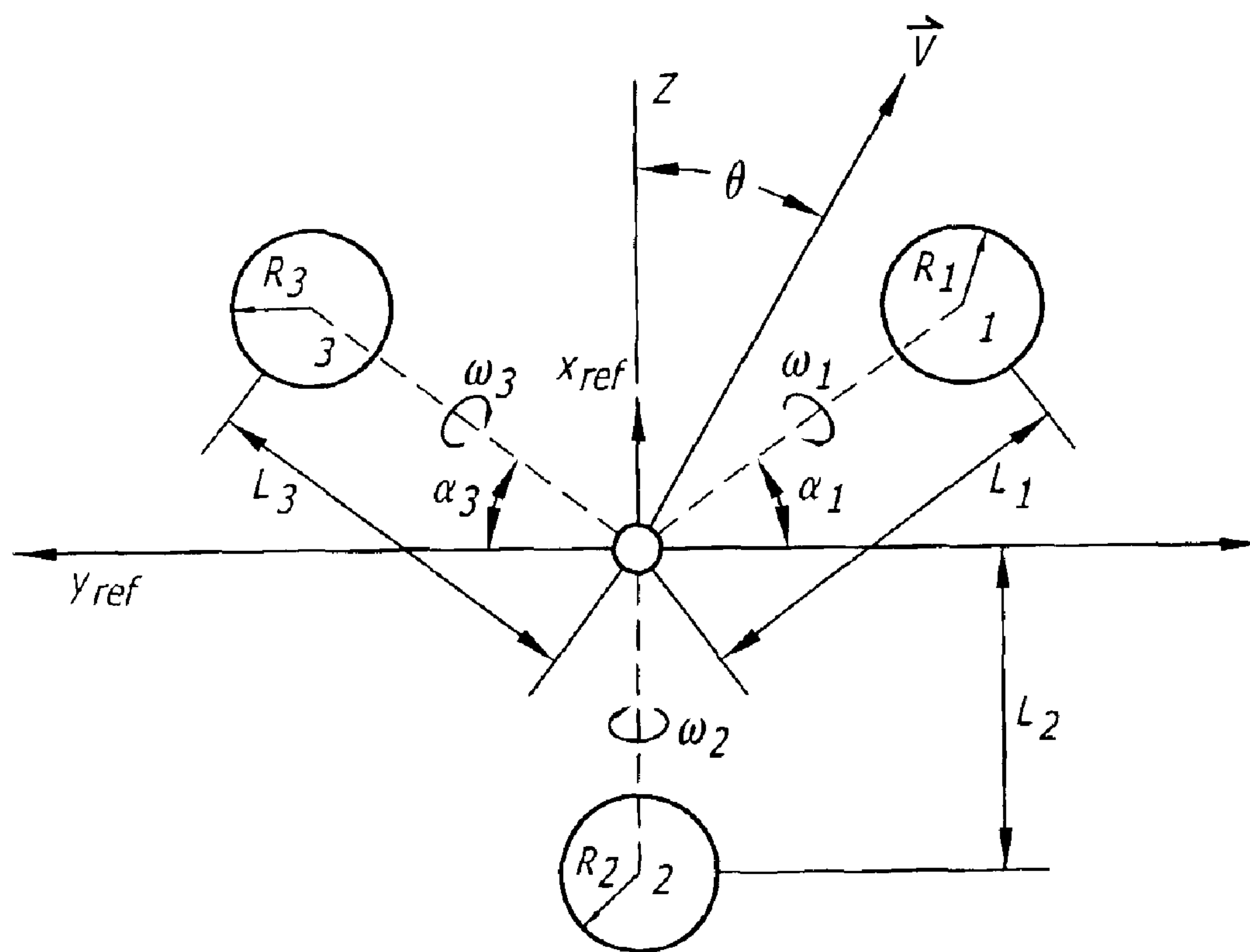


FIG. 10

*FIG. 11*

MEDICAL TELE-ROBOTIC SYSTEM**BACKGROUND OF THE INVENTION****1. Field of the Invention**

The subject matter disclosed generally relates to the field of robotics used in the medical field.

2. Background Information

There is a growing need to provide remote health care to patients that have a variety of ailments ranging from Alzheimers to stress disorders. To minimize costs it is desirable to provide home care for such patients. Home care typically requires a periodic visit by a health care provider such as a nurse or some type of assistant. Due to financial and/or staffing issues the health care provider may not be there when the patient needs some type of assistance. Additionally, existing staff must be continuously trained, which can create a burden on training personnel. It would be desirable to provide a system that would allow a health care provider to remotely care for a patient without being physically present.

Robots have been used in a variety of applications ranging from remote control of hazardous material to assisting in the performance of surgery. For example, U.S. Pat. No. 5,762,458 issued to Wang et al. discloses a system that allows a surgeon to perform minimally invasive medical procedures through the use of robotically controlled instruments. There have also been developed "toy" robots for home use. Such robots typically have a relatively simple movement platform and some type of speech synthesis for generating words and sounds. It would be desirable to provide a robotic system that would allow for remote patient monitoring and assistance.

BRIEF SUMMARY OF THE INVENTION

A robot that may include a camera and a monitor that are attached to a housing. The robot may also have a platform that is attached to the housing and coupled to a controller. The controller may be coupled to a broadband interface.

BRIEF DESCRIPTION OF THE DRAWINGS

- FIG. 1 is an illustration of a robotic system;
- FIG. 2 is a schematic of an electrical system of a robot;
- FIG. 3 is a further schematic of the electrical system of the robot;
- FIG. 4 is an illustration of a robot with an arm in an upward position;
- FIG. 5 is an illustration of the robot with the arm in a lower position;
- FIG. 6 is an illustration of a holonomic platform of the robot;
- FIG. 7 is an illustration of a roller assembly of the holonomic platform;
- FIG. 8 is an illustration of an arm assembly of the robot;
- FIG. 9 is an illustration of a gripper assembly of the arm;
- FIG. 10 is a schematic of a battery recharger for the robot;
- FIG. 11 is a vector diagram that may be used to compute movement of the robot.

DETAILED DESCRIPTION

Disclosed is a robotic system that includes a remote controlled robot. The robot may include a camera, a monitor and a holonomic platform all attached to a robot housing.

The robot may be controlled by a remote control station that also has a camera and a monitor. The remote control station may be linked to a base station that is wirelessly coupled to the robot. The cameras and monitors allow a care giver at the remote location to monitor and care for a patient through the robot. The holonomic platform allows the robot to move about a home or facility to locate and/or follow a patient.

Referring to the drawings more particularly by reference numbers, FIG. 1 shows a robotic system 10. The robotic system 10 includes a robot 12, a base station 14 and a remote control station 16. The remote control station 16 may be coupled to the base station 14 through a network 18. By way of example, the network 18 may be either a packet switched network such as the Internet, or a circuit switched network such as a Public Switched Telephone Network (PSTN) or other broadband system. The base station 14 may be coupled to the network 18 by a modem 20 or other broadband network interface device.

The remote control station 16 may include a computer 22 that has a monitor 24, a camera 26, a microphone 28 and a speaker 30. The computer 22 may also contain an input device 32 such as a joystick or a mouse. The control station 16 is typically located in a place that is remote from the robot 12. Although only one remote control station 16 is shown, the system 10 may include a plurality of remote stations. Additionally, although only one robot 12 is shown, it is to be understood that the system 10 may have a plurality of robots 12. In general any number of robots 12 may be controlled by any number of remote stations. For example, one remote station 16 may be coupled to a plurality of robots 12, or one robot 12 may be coupled to a plurality of remote stations 16.

The robot 12 includes a movement platform 34 that is attached to a robot housing 36. Also attached to the robot housing 36 are a camera 38, a monitor 40, a microphone(s) 42 and a speaker 44. The microphone 42 and speaker 30 may create a stereophonic sound. The robot 12 may also have an antennae 45 that is wirelessly coupled to an antennae 46 of the base station 14. The system 10 allows a user at the remote control station 16 to move the robot 12 through the input device 32. The robot camera 38 is coupled to the remote monitor 24 so that a user at the remote station 16 can view a patient. Likewise, the robot monitor 40 is coupled to the remote camera 26 so that the patient can view the user. The microphones 28 and 42, and speakers 30 and 44, allow for audible communication between the patient and the user.

The remote station computer 22 may operate Microsoft OS software and WINDOWS XP or other operating systems such as LINUX. The remote computer 22 may also operate a video driver, a camera driver, an audio driver and a joystick driver. The video images may be transmitted and received with compression software such as MPEG CODEC.

FIGS. 2 and 3 show an embodiment of the robot 12. The robot 12 may include a high level control system 50 and a low level control system 52. The high level control system 50 may include a processor 54 that is connected to a bus 56. The bus is coupled to the camera 38 by an input/output (I/O) port 58, and to the monitor 40 by a serial output port 60 and a VGA driver 62. The monitor 40 may include a touchscreen function that allows the patient to enter input by touching the monitor screen.

The speaker 44 is coupled to the bus 56 by a digital to analog converter 64. The microphone 42 is coupled to the bus 56 by an analog to digital converter 66. The high level controller 50 may also contain random access memory (RAM) device 68, a non-volatile RAM device 70 and a mass storage device 72 that are all coupled to the bus 62. The mass

storage device **72** may contain medical files of the patient that can be accessed by the user at the remote control station **16**. For example, the mass storage device **72** may contain a picture of the patient. The user, particularly a health care provider, can recall the old picture and make a side by side comparison on the monitor **24** with a present video image of the patient provided by the camera **38**. The robot antennae **44** may be coupled to a wireless transceiver **74**. By way of example, the transceiver **74** may transmit and receive information in accordance with IEEE 802.11a.

The controller **54** may operate with a LINUX OS operating system. The controller **54** may also operate X WINDOWS along with video, camera and audio drivers for communication with the remote control station **16**. Video information may be transceived using MPEG CODEC compression techniques. The software may allow the user to send e-mail to the patient and vice versa, or allow the patient to access the Internet. In general the high level controller **50** operates to control the communication between the robot **12** and the remote control station **16**.

The high level controller **50** may be linked to the low level controller **52** by serial ports **76** and **78**. The low level controller **52** includes a processor **80** that is coupled to a RAM device **82** and non-volatile RAM device **84** by a bus **86**. The robot **12** contains a plurality of motors **88** and motor encoders **90**. The encoders **90** provide feedback information regarding the output of the motors **88**. The motors **88** can be coupled to the bus **86** by a digital to analog converter **92** and a driver amplifier **94**. The encoders **90** can be coupled to the bus **86** by a decoder **96**. The robot **12** also has a number of proximity sensors **98** (see also FIG. 1). The position sensors **98** can be coupled to the bus **86** by a signal conditioning circuit **100** and an analog to digital converter **102**.

The low level controller **52** runs software routines that mechanically actuate the robot **12**. For example, the low level controller **52** provides instructions to actuate the movement platform to move the robot **12**, or to actuate an arm of the robot. The low level controller **52** may receive movement instructions from the high level controller **50**. The movement instructions may be received as movement commands from the remote control station. Although two controllers are shown, it is to be understood that the robot **12** may have one controller controlling the high and low level functions.

The various electrical devices of the robot **12** may be powered by a battery(ies) **104**. The battery **104** may be recharged by a battery recharger station **106** (see also FIG. 1). The low level controller **52** may include a battery control circuit **108** that senses the power level of the battery **104**. The low level controller **52** can sense when the power falls below a threshold and then send a message to the high level controller **50**. The high level controller **50** may include a power management software routine that causes the robot **12** to move so that the battery **104** is coupled to the recharger **106** when the battery power falls below a threshold value. Alternatively, the user can direct the robot **12** to the battery recharger **106**. Additionally, the battery may be replaced or the robot **12** may be coupled to a wall power outlet by an electrical cord (not shown).

FIG. 4 shows an embodiment of the robot **12**. The robot **12** may include a holonomic platform **110** that is attached to a robot housing **112**. The holonomic platform **110** allows the robot **12** to move in any direction. Although not shown the robot housing **112** may include bumpers.

The robot **12** may have an arm **114** that supports the camera **38** and monitor **40**. The arm **114** may have two

degrees of freedom so that the camera **26** and monitor **24** can be moved from an upper position shown in FIG. 4 to a lower position shown in FIG. 5. The arm **114** may have an end effector **116** such as a gripper that can grasp objects.

The robot **12** may include a drawer **118** that can automatically move between a closed position and an open position. The drawer **118** can be used to dispense drugs to a patient. For example, the drawer **118** may include a drug(s) that must be taken at a certain time. The robot **12** may be programmed so that the drawer **118** is opened at the desired time. A nurse or other health care provider may periodically "load" the drawer **118**. The robot may also have a battery recharger port **119**. Although drugs are described, it is to be understood that the drawer **118** could hold any item.

As shown in FIG. 6 the holonomic platform **110** may include three roller assemblies **120** that are mounted to a base plate **122**. The roller assemblies **120** are typically equally spaced about the platform **110** and allow for movement in any direction.

FIG. 7 shows an embodiment of a roller assembly **120**. Each assembly **120** may include a drive ball **124** that is driven by a pair of transmission rollers **126**. The assembly **120** includes a retainer ring **128** and a plurality of bushings **130** that allow the ball **124** to rotate in an x and y direction but prevents movement in a z direction.

The transmission rollers **126** are coupled to a motor assembly **132**. The assembly **132** corresponds to the motor **88** shown in FIG. 3. The motor assembly **132** includes an output pulley **134** attached to a motor **136**. The output pulley **134** is coupled to a pair of ball pulleys **138** by a drive belt **140**. The ball pulleys **138** are attached to drive pins **142** that are attached to a transmission bracket **144**. The transmission rollers **126** are attached to a transmission bracket **144** by a roller pin **146**. The transmission brackets **144** each have a pin **143** that is supported by a part of the housing.

Rotation of the output pulley **134** rotates the ball pulleys **138**. Rotation of the ball pulleys **138** causes the transmission rollers **126** to rotate and spin the ball **124** through frictional forces. Spinning the ball **124** will move the robot **12**. The drive balls **126** are out of phase so that one of the balls **126** is always in contact with ball **124**. The roller pin **146** and bracket **144** allow the transmission rollers **126** to freely spin and allow orthogonal directional passive movement when one of the other roller assemblies **120** is driving and moving the robot **12**.

FIGS. 8 and 9 show an embodiment of the arm **114**. The arm **114** may include a first linkage **150** that is pivotally mounted to a fixed plate **152** of the robot housing **12**. The arm **114** may also include a second linkage **154** that is pivotally connected to the first linkage **150** and a third linkage **156** that is pivotally connected to the second linkage **154**.

The first linkage **150** may be coupled to a first motor **158** and motor encoder **160** by a gear assembly **162**. Rotation of the motor **158** will cause a corresponding pivotal movement of the linkage **150** and arm **114**. The linkage **150** may be coupled to the fixed plate **152** by a bearing **164**.

The second linkage **154** may be coupled to a second motor **166** and encoder **168** by a gear assembly **170** and a pulley assembly **172**. The pulley assembly **172** may be connected to the gear assembly **170** by a pin **174** that extends through the gear assembly **162** of the first motor **158**. The second linkage **154** may be attached to a pin **176** that can spin relative to the first linkage **150**. The pulley assembly **172** may have a belt **178** that couples a pair of pulleys **180** and **182** that are attached to pins **174** and **176**, respectively. Pin

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176 may be coupled to the first linkage 150 by bearings 182. The arm 114 is configured to allow wires 183 to be internally routed through the linkages 150, 154 and 156.

The third linkage 156 may be connected to a pin 184 that can spin relative to the second linkage 154. The pin 184 may be coupled to the second linkage 154 by a bearing assembly 186. The third linkage 156 may be structurally coupled to the first linkage 150 by a pair of pulley assemblies 188. The pulley assembly 188 insures a horizontal position of the third linkage 156 no matter what position the first 150 and second 154 linkages are in. As shown in FIGS. 4 and 5 the third linkage 156 is always in a horizontal position. This insures that the camera 26 is always in the same orientation, thus reducing the possibility of disorientation at the remote control station when viewing the patient.

The gripper 116 is attached to the third linkage 156. The gripper 116 may include a pair of fingers 190 that are pivotally attached to a base plate 192. The fingers 190 are coupled to a motor 194 and encoder 196 by a gear assembly 198. The base plate 192 is coupled to the third linkage 156 by a bearing assembly 200. The motor 194 can spin the base plate 192 and fingers 192 relative to the third linkage 156.

The gripper 116 may further have a push rod 202 that can engage cam surfaces 204 of the fingers 190 to move the gripper fingers 190 between open and closed positions. The push rod 202 may be coupled to a motor 206 and encoder (not shown) by a linkage assembly 208. Actuation of the motor 206 will translate the push rod 202 and move the fingers 190. The motor 206 may have a force sensor that provides force feedback back to the remote control station. The input device of the remote control station may have a force feedback mechanism so that the user feels the force being exerted onto the gripper fingers 190.

In operation, the robot 12 may be placed in a home or a facility where one or more patients are to be monitored and/or assisted. The facility may be a hospital or a residential care facility. By way of example, the robot 12 may be placed in a home where a health care provider may monitor and/or assist the patient. Likewise, a friend or family member may communicate with the patient. The cameras and monitors at both the robot and remote control station allow for teleconferencing between the patient and the person at the remote station.

The robot 12 can be maneuvered through the home or facility by manipulating the input device 32 at the remote station 16. The robot 12 may also have autonomous movement. For example, the robot 12 may be programmed to automatically move to a patients room at a certain time to dispense drugs in the drawer 118 without input from the remote station 16. The robot 12 can be programmed to monitor and/or assist a patient 24 hours a day, 7 days a week. Such a monitoring capability is enhanced by the autonomous recharging function of the robot.

The robot 10 may be controlled by a number of different users. To accommodate for this the robot may have an arbitration system. The arbitration system may be integrated into the operating system of the robot 12. For example, the arbitration technique may be embedded into the operating system of the high-level controller 50.

By way of example, the, users may be divided into classes that include the robot itself, a local user, a caregiver, a doctor, a family member, or a service provider. The robot may override input commands that conflict with robot operation. For example, if the robot runs into a wall, the system may ignore all additional commands to continue in the direction of the wall. A local user is a person who is

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physically present with the robot. The robot could have an input device that allows local operation. For example, the robot may incorporate a voice recognition system that receives and interprets audible commands.

A caregiver is someone who remotely monitors the patient. A doctor is a medical professional who can remotely control the robot and also access medical files contained in the robot memory. The family and service users remotely access the robot. The service user may service the system such as by upgrading software, or setting operational parameters.

Message packets may be transmitted between a robot 12 and a remote station 16. The packets provide commands and feedback. Each packet may have multiple fields. By way of example, a packet may include an ID field a forward speed field, an angular speed field, a stop field, a bumper field, a sensor range field, a configuration field, a text field and a debug field.

The identification of remote users can be set in an ID field of the information that is transmitted from the remote control station 16 to the robot 12. For example, a user may enter a user ID into a setup table in the application software run by the remote control station 16. The user ID is then sent with each message transmitted to the robot.

The robot 12 may operate in one of two different modes; an exclusive mode, or a sharing mode. In the exclusive mode only one user has access control of the robot. The exclusive mode may have a priority assigned to each type of user. By way of example, the priority may be in order of local, doctor, caregiver, family and then service user. In the sharing mode two or more users may share access with the robot. For example, a caregiver may have access to the robot, the caregiver may then enter the sharing mode to allow a doctor to also access the robot. Both the caregiver and the doctor can conduct a simultaneous tele-conference with the patient.

The arbitration scheme may have one of four mechanisms; notification, timeouts, queue and call back. The notification mechanism may inform either a present user or a requesting user that another user has, or wants, access to the robot. The timeout mechanism gives certain types of users a prescribed amount of time to finish access to the robot. The queue mechanism is an orderly waiting list for access to the robot. The call back mechanism informs a user that the robot can be accessed. By way of example, a family user may receive an e-mail message that the robot is free for usage. Tables 1 and 2, show how the mechanisms resolve access request from the various users.

TABLE I

User	Access Control	Medical Record	Command Override	Software/ Debug Access	Set Priority
Robot	No	No	Yes (1)	No	No
Local	No	No	Yes (2)	No	No
Caregiver	Yes	Yes	Yes (3)	No	No
Doctor	No	Yes	No	No	No
Family	No	No	No	No	No
Service	Yes	No	Yes	Yes	Yes

TABLE II

		Requesting User				
		Local	Caregiver	Doctor	Family	Service
Current User	Local	Not Allowed	Warn current user of pending user Notify requesting user that system is in use Set timeout	Warn current user of pending user Notify requesting user that system is in use Set timeout = 5 m	Warn current user of pending user Notify requesting user that system is in use Set timeout = 5 m Call back	Warn current user of pending user Notify requesting user that system is in use No timeout Call back
	Caregiver	Warn current user of pending user Notify requesting user that system is in use. Release control	Not Allowed	Warn current user of pending user Notify requesting user that system is in use Set timeout = 5 m Queue or callback	Warn current user of pending user Notify requesting user that system is in use Set timeout = 5 m	Warn current user of pending user Notify requesting user that system is in use No timeout Callback
	Doctor	Warn current user of pending user Notify requesting user that system is in use Release control	Warn current user of pending user Notify requesting user that system is in use Set timeout = 5 m	Warn current user of pending user Notify requesting user that system is in use No timeout Callback	Notify requesting user that system is in use No timeout Queue or callback	Warn current user of pending user Notify requesting user that system is in use No timeout Callback
	Family	Warn current user of pending user Notify requesting user that system is in use Release Control	Notify requesting user that system is in use No timeout Put in queue or callback	Warn current user of pending user Notify requesting user that system is in use Set timeout = 1 m	Warn current user of pending user Notify requesting user that system is in use Set timeout = 5 m Queue or callback	Warn current user of pending user Notify requesting user that system is in use No timeout Callback
	Service	Warn current user of pending user Notify requesting user that system is in use No timeout	Notify requesting user that system is in use No timeout Callback	Warn current user of request Notify requesting user that system is in use No timeout Callback	Warn current user of pending user Notify requesting user that system is in use No timeout Queue or callback	Not Allowed

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The information transmitted between the station **16** and the robot **12** may be encrypted. Additionally, the user may have to enter a password to enter the system **10**. A selected robot is then given an electronic key by the station **16**. The robot **12** validates the key and returns another key to the station **16**. The keys are used to encrypt information transmitted in the session.

FIG. **10** shows an embodiment of a battery recharger. The robot port **119** may include a secondary winding **250** that is magnetically coupled to a primary winding **252** of the battery recharger station **106**. The primary winding **252** is coupled to an electrical outlet plug **254** by a relay circuit **256**, a fuse **258** and a switch **260**. The relay **256** is controlled by a recharger controller **262**.

The recharger controller **262** is connected to a recharger infrared (IR) transceiver **264**. The recharger IR transceiver **264** is coupled to a robot IR transceiver **266**. The robot IR transceiver **266** is connected to the low level controller **52**. The robot **10** may also have an alignment sensor **268** that can sense a target **270** on the station **106**. By way of example, the sensor **268** may include an optical emitter and receiver that detects a light beam reflected from the target **270**. The controller **52** may also sense a current flow into the battery **104** to determine whether the robot **12** is aligned with the docking station **106**.

The secondary windings **250** are connected to the battery **104** by a charger circuit **272**. The secondary **250** and primary **252** windings may each have wires **274** wrapped about a magnetic core **276**. The station **106** may also have an oscillator/chopper circuit (not shown) to increase the voltage magnetically transferred to the secondary winding **250**.

In operation, the robot **10** is moved to the battery recharger station **106** either autonomously, or by user control. The robot **10** is moved until the sensor **268** is aligned with the target **270**. The low level controller **52** then sends a command to the recharger controller **262** through the transceivers **264** and **266**. The recharger controller **262** then closes the relay **256** wherein power is transferred to the battery **104** through the windings **250** and **252**. When the battery **104** is recharged, or the battery recharging process is interrupted by the user, the low level controller **52** transmits a command to the recharger controller **262** to open the relay **256**. The robot **10** then moves away from the recharging station **106**.

FIG. **11** shows a vector diagram that can be used to compute movement of the robot with the following equations:

$$w_1 = \frac{|V|}{R_1} (\sin \alpha_1 \sin \theta - \cos \alpha_1 \cos \theta) + \frac{\Psi L_1}{R_1} \quad (1)$$

$$w_2 = \frac{|V|}{R_2} \sin \theta + \frac{\Psi L_2}{R_2} \quad (2)$$

$$w_3 = \frac{|V|}{R_3} (\sin \alpha_3 \sin \theta + \cos \alpha_3 \cos \theta) + \frac{\Psi L_3}{R_3} \quad (3)$$

where,

w_1 =is the drive angular velocity of a first ball **124**.

w_2 =is the drive angular velocity of a second ball **124**.

w_3 =is the drive angular velocity of a third ball **124**.

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V is the input linear velocity for the robot. V has components V_x and V_y , where; $V_x = |V| \cos \theta$ and $V_y = |V| \sin \theta$.
 ψ is the input angular velocity for the robot.

Let the angular velocity vector

$$w = [w_1, w_2, w_3]^T. \quad (4)$$

$$A = \begin{bmatrix} -\frac{\cos \alpha_1}{R_1} & \frac{\sin \alpha_1}{R_1} & \frac{L_1}{R_1} \\ 0 & -\frac{1}{R_2} & \frac{L_2}{R_2} \\ \frac{\cos \alpha_3}{R_3} & \frac{\sin \alpha_3}{R_3} & \frac{L_3}{R_3} \end{bmatrix} \quad (5)$$

and the velocity vector:

$$V = [v_x, v_y, \psi]^T \quad (6)$$

$$W = A \cdot V \quad (7)$$

The angular velocity vector w is calculated from equation (7) and compared with the actual w values measured by the motor encoder. An algorithm performs an error correction routine to compensate for differences in the actual and desired values.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art.

What is claimed is:

1. A method for remotely operating a robot to monitor a patient, comprising:

transmitting a first command to move a mobile robot from a first remote control station;

transmitting a second command to move the mobile robot from a second remote control station;

determining which command has priority; and,

moving the mobile robot in response to the transmitted command with priority.

2. The method of claim 1, further comprising transmitting a video image from the mobile robot to the remote control station.

3. The method of claim 2, wherein an existing video image and a pre-existing video image is transmitted to the remote control station from the mobile robot.

4. The method of claim 1, further comprising transmitting a video image from the remote control station to the mobile robot.

5. The method of claim 1, further comprising moving a drawer of the mobile robot to an open position to dispense a drug.

6. The method of claim 1, wherein the robot autonomously moves to a battery recharger station.

7. A robot, comprising:

a housing;

a movement platform attached to said housing;

a camera attached to said housing;

a mass storage device that stores a pre-existing video image of a patient; and,

a controller coupled to said movement platform.

8. The robot of claim 7, further comprising an arm coupled to said housing.

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9. The robot of claim 8, wherein said arm includes a gripper.

10. The robot of claim 7, further comprising a speaker coupled to said housing.

11. The robot of claim 7, further comprising a microphone coupled to said housing.

12. The robot of claim 7, further comprising a wireless transceiver coupled to said housing.

13. The robot of claim 7, further comprising a battery recharger station, a battery that is coupled to said housing and can be coupled to said battery recharger station, and a power management software routine wherein said holonomic platform moves said housing so that said battery is coupled to said battery recharger station.

14. The robot of claim 7, wherein said movement platform includes a plurality of roller assemblies.

15. The robot of claim 7, wherein said controller runs a routine to moves a drawer of said housing to an open position.

16. A method for monitoring a patient, comprising:
 storing a pre-existing video image of a patient;
 capturing an existing video image of the patient; and,
 transmitting the pre-existing video image and the existing video image to a remote control station.

17. The method of claim 16, wherein the robot is remotely controlled.

18. A robot system, comprising:

a battery recharger station;

a robot housing;

a battery coupled to said robot housing;

a movement platform attached to said robot housing;

a camera attached to said robot housing; and,

a controller that is attached to said robot housing and coupled to said movement platform, said controller operates a power management software routine that causes said movement platform to move said robot housing so that said battery is coupled to said battery recharger.

19. The robot system of claim 18, further comprising an arm coupled to said robot housing.

20. The robot system of claim 19, wherein said arm includes a gripper.

21. The robot system of claim 18, further comprising a speaker coupled to said robot housing.

22. The robot system of claim 18, further comprising a microphone coupled to said robot housing.

23. The robot system of claim 18, further comprising a wireless transceiver coupled to said robot housing.

24. The robot system of claim 18, wherein said movement platform includes a plurality of roller assemblies.

25. The robot system of claim 18, further comprising a mass storage device that stores a video image.

26. A method for operating a robot, comprising:
 operating a software routine within a robot to determine whether the robot needs power; and,
 moving the robot to a battery recharger station when the robot needs power.

27. The method of claim 26, wherein the robot is remotely controlled.

28. A system for remotely visiting a person located in a healthcare facility, comprising:

a broadband network;

a remote station that is coupled to said broadband network, said remote station includes a monitor, a speaker and an input device to generate a robot command; and,

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a robot that is coupled to said remote station through said broadband network, said robot having a camera that captures video of a person that is transmitted to said remote station and a microphone that captures audio from the person that is transmitted to said remote station, said robot moves across a surface of the health-care facility in response to receiving said robot command from said remote station.

29. The system of claim 28, wherein said remote station includes a camera and a microphone and said robot includes a monitor and a speaker.

30. The system of claim 28, wherein said robot includes a holonomic platform.

31. The system of claim 28, wherein said robot includes a wireless transceiver.

32. The system of claim 28, wherein said remote station includes a computer.

33. The system of claim 28, wherein said remote station is assigned a family priority.

34. The system of claim 28, wherein said input device is a joystick.

35. The system of claim 28, wherein said broadband network is a packet switched network.

36. The system of claim 28, wherein said robot is located in a hospital.

37. The system of claim 28, wherein said robot is located in a residential care facility.

38. A system for remotely visiting a person located in a healthcare facility, comprising:

broadband network means for transmitting information;

remote station means for receiving video and audio transmitted through said broadband network means and generating a robot command that is transmitted through said broadband network means; and,

robot means for capturing video and audio of a person that is transmitted to said remote station means through said broadband network means, and moving across a surface of the healthcare facility in response to receiving said robot command from said remote station means through said broadband network means.

39. The system of claim 38, wherein said remote station means transmits video and audio to said robot means through said broadband network means.

40. The system of claim 38, wherein said robot means includes a holonomic platform.

41. The system of claim 38, wherein said robot means includes a wireless transceiver.

42. The system of claim 38, wherein said remote station means includes a computer.

43. The system of claim 38, wherein said remote station means is assigned a family priority.

44. The system of claim 38, wherein said remote station means includes a joystick to generate said robot command.

45. The system of claim 38, wherein said robot means is located in a hospital.

46. The system of claim 38, wherein said robot means is located in a residential care facility.

47. A robot system, comprising:

a mobile robot that has a camera and a monitor;

a first remote station that can access said mobile robot;

a second remote station that can access said mobile robot;

and,

an arbitrator that can control access to said mobile robot by said first and second remote stations.

48. The system of claim 47, wherein said arbitrator includes a notification mechanism.

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49. The system of claim 47, wherein said arbitrator includes a timeout mechanism.

50. The system of claim 47, wherein said arbitrator includes a queue mechanism.

51. The system of claim 47, wherein said arbitrator includes a call back mechanism.

52. The system of claim 47, wherein said first and second remote stations each have a priority and said arbitrator provides robot access to said remote station with a highest priority.

53. The system of claim 52, wherein said first and second remote stations may be given priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

54. The system of claim 47, wherein said arbitrator is located within said robot.

55. A robot system, comprising:

a mobile robot that has a camera and a monitor;

a first remote station that can access said mobile robot;

a second remote station that can access said mobile robot;

and,

arbitration means for controlling access to said mobile robot by said first and second remote stations.

56. The system of claim 55, wherein said arbitrator means includes notification means for notifying said first remote station that said second remote station is requesting access to said mobile robot.

57. The system of claim 55, wherein said arbitrator means includes timeout means that creates a time interval in which one of said remote stations must relinquish access to said mobile robot.

58. The system of claim 55, wherein said arbitrator means includes queue means for establishing a waiting list of remote stations seeking access to said mobile robot.

59. The system of claim 55, wherein said arbitrator means includes call back means for providing a message to one of said remote stations that said mobile robot can be accessed.

60. The system of claim 55, wherein said first and second remote stations each have a priority and said arbitrator means provides robot access to said remote station with a highest priority.

61. The system of claim 60, wherein said first and second remote stations may be given priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

62. The system of claim 55, wherein said arbitrator means is located within said robot.

63. A robot system, comprising:

a broadband network;

a mobile robot that is coupled to said broadband network, and has a camera and a monitor;

a first remote station that can access said mobile robot through said broadband network;

a second remote station that can access said mobile robot through said broadband network; and,

an arbitrator that can control access to said mobile robot by said first and second remote stations.

64. The system of claim 63, wherein said arbitrator includes a notification mechanism.

65. The system of claim 63, wherein said arbitrator includes a timeout mechanism.

66. The system of claim 63, wherein said arbitrator includes a queue mechanism.

67. The system of claim 63, wherein said arbitrator includes a call back mechanism.

68. The system of claim 63, wherein said first and second remote stations each have a priority and said arbitrator provides robot access to said remote station with a highest priority.

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69. The system of claim 68, wherein said first and second remote stations may be given priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

70. The system of claim 63, wherein said arbitrator is 5 located within said robot.

71. A robot system, comprising:

a broadband network;

a mobile robot that is coupled to said broadband network, 10 and has a camera and a monitor;

a first remote station that can access said mobile robot through said broadband network;

a second remote station that can access said mobile robot through said broadband network; and, 15

arbitration means for controlling access to said robot by said first and second remote stations.

72. The system of claim 71, wherein said arbitrator means includes notification means for notifying said first remote station that said second remote station is requesting access 20 to said mobile robot.

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73. The system of claim 71, wherein said arbitrator means includes timeout means that creates a time interval in which one of said remote stations must relinquish access to said mobile robot.

74. The system of claim 71, wherein said arbitrator means includes queue means for establishing waiting list of remote stations seeking access to said mobile robot.

75. The system of claim 71, wherein said arbitrator means includes call back means for providing a message to one of said remote stations that said mobile robot can be accessed.

76. The system of claim 71, wherein said first and second remote stations each have a priority and said arbitrator means provides robot access to said remote station with a highest priority.

77. The system of claim 76, wherein said first and second remote stations may be given priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

78. The system of claim 71, wherein said arbitrator means is located within said robot.

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US006925357C1

(12) **EX PARTE REEXAMINATION CERTIFICATE (7501st)**
United States Patent
Wang et al.

(10) **Number:** **US 6,925,357 C1**
(45) **Certificate Issued:** **May 11, 2010**

(54) **MEDICAL TELE-ROBOTIC SYSTEM**

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Reexamination Request:

No. 90/009,291, Sep. 30, 2008

Reexamination Certificate for:

Patent No.: **6,925,357**
Issued: **Aug. 2, 2005**
Appl. No.: **10/206,457**
Filed: **Jul. 25, 2002**

(51) **Int. Cl.**

G06F 11/00 (2006.01)
G06F 19/00 (2006.01)
G06F 15/00 (2006.01)
B25J 5/00 (2006.01)
B25J 9/00 (2006.01)

- (52) **U.S. Cl.** **700/245**; 318/568.12; 348/E7.088;
700/246; 700/250; 700/254; 700/260; 700/261;
700/262; 702/188; 901/1; 901/2
- (58) **Field of Classification Search** None
See application file for complete search history.

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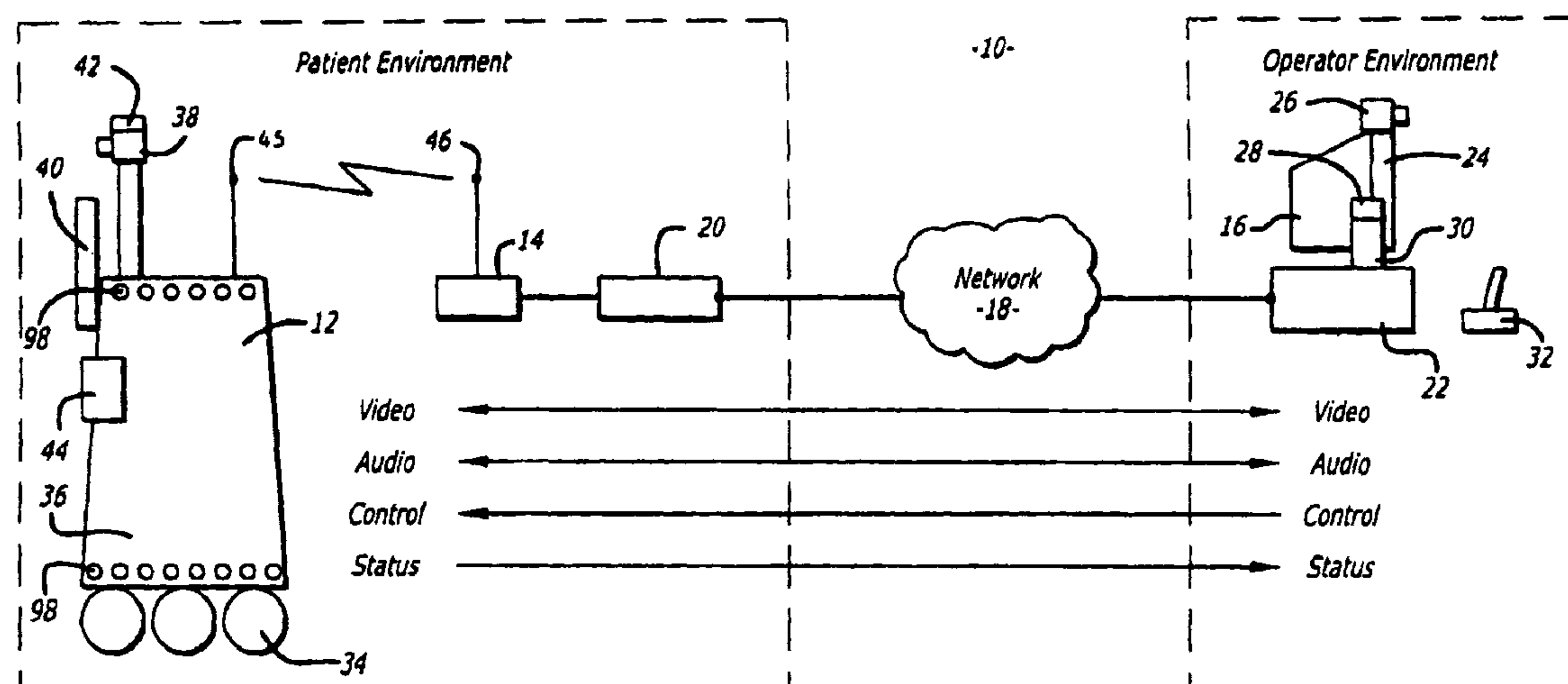
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Primary Examiner—Peter C. English

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ABSTRACT

A robotic system that includes a remote controlled robot. The robot may include a camera, a monitor and a holonomic platform all attached to a robot housing. The robot may be controlled by a remote control station that also has a camera and a monitor. The remote control station may be linked to a base station that is wirelessly coupled to the robot. The cameras and monitors allow a care giver at the remote location to monitor and care for a patient through the robot. The holonomic platform allows the robot to move about a home or facility to locate and/or follow a patient.



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EX PARTE
REEXAMINATION CERTIFICATE
ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS
INDICATED BELOW.

Matter enclosed in heavy brackets [] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims 1–46, 48–51, 56–59, 64–67 and 72–75 are cancelled.

Claims 47, 52, 53, 55, 60–63, 68, 69, 71 and 76–78 are determined to be patentable as amended.

Claims 54 and 70, dependent on an amended claim, are determined to be patentable.

New claims 79–94 are added and determined to be patentable.

47. A robot system, comprising:

a mobile robot that has a camera and a monitor;
a first remote station that can access said mobile robot;
a second remote station that can access said mobile robot;
and,

an arbitrator that can control access to said mobile robot by said first and second remote stations, *said arbitrator includes a notification mechanism that warns a present user that access to said mobile robot will be terminated because another user with higher priority wants access to said mobile robot.*

52. The system of claim 47, wherein said first and second remote stations each have a *class* priority and said arbitrator provides robot access to said remote station with a highest priority.

53. The system of claim 52, wherein said first and second remote stations may be given *said class* priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

55. A robot system, comprising:

a mobile robot that has a camera and a monitor;
a first remote station that can access said mobile robot;
a second remote station remote station that can access said mobile robot; and,

arbitration means for controlling access to said mobile robot by said first and second remote stations, *said arbitration means includes notification means for warning a present user that access to said mobile robot will be terminated because another user with higher priority wants access to said mobile robot.*

60. The system of claim 55, wherein said first and second remote stations each have a *class* priority and said [arbitrator] *arbitration* means provides robot access to said remote station with a highest priority.

61. The system of claim 60, wherein said first and second remote stations may be given *said class* priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

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62. The system of claim 55, wherein said [arbitrator] *arbitration* means is located within said robot.

63. A robot system, comprising:

a broadband network;

a mobile robot that is coupled to said broadband network, and has a camera and a monitor;

a first remote station that can access said mobile robot through said broadband network;

a second remote station that can access said mobile robot through said broadband network; and,

an arbitrator that can control access to said mobile robot by said first and second remote stations, *said arbitrator includes a notification mechanism that warns a present user that access to said mobile robot will be terminated because another user with higher priority wants access to said mobile robot.*

68. The system of claim 63, wherein said first and second remote stations each have a *class* priority and said arbitrator provides robot access to said remote station with a highest priority.

69. The system of claim 68, wherein said first and second remote stations may be given *said class* priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

71. A robot system, comprising:

a broadband network;

a mobile robot that is coupled to said broadband network, and has a camera and a monitor;

a first remote station that can access said mobile robot through said broadband network;

a second remote station that can access said mobile robot through said broadband network; and,

arbitration means for controlling access to said robot by said first and second remote stations, *said arbitration means includes notification means for warning a present user that access to said mobile robot will be terminated because another user with higher priority wants access to said mobile robot.*

76. The system of claim 71, wherein said first and second remote stations each have a *class* priority and said [arbitrator] *arbitration* means provides robot access to said remote station with a highest priority.

77. The system of claim 76, wherein said first and second remote stations may be given *said class* priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

78. The system of claim 71, wherein said [arbitrator] *arbitration* means is located within said robot.

79. A robot system, comprising:

a mobile robot that has a camera and a monitor;

a first remote station that can access said mobile robot;

a second remote station that can access said mobile robot; and,

an arbitrator that can control access to said mobile robot by said first and second remote stations, *said arbitrator includes a call back mechanism that informs a user that was denied access to said mobile robot that said mobile robot can be accessed.*

80. The system of claim 79, wherein said first and second remote stations each have a *class* priority and said arbitrator provides robot access to said remote station with a highest priority.

81. The system of claim 80, wherein said first and second remote stations may be given *said class* priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

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82. The system of claim 79, wherein said arbitrator is located within said robot.

83. A robot system, comprising:

a mobile robot that has a camera and a monitor;

a first remote station that can access said mobile robot; 5

a second remote station that can access said mobile robot;

and,

arbitration means for controlling access to said mobile robot by said first and second remote stations, said arbitration means includes call back means for providing a message to one of said remote stations that was denied access to said mobile robot that said mobile robot can be accessed.

84. The system of claim 83, wherein said first and second remote stations each have a class priority and said arbitration means provides robot access to said remote station with a highest priority. 15

85. The system of claim 84, wherein said first and second remote stations may be given said class priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot. 20

86. The system of claim 83, wherein said arbitration means is located within said robot.

87. A robot system, comprising:

a broadband network;

a mobile robot that is coupled to said broadband network, and has a camera and a monitor;

a first remote station that can access said mobile robot through said broadband network;

a second remote station that can access said mobile robot through said broadband network; and, 30

an arbitrator that can control access to said mobile robot by said first and second remote stations, said arbitrator includes a call back mechanism that informs a user that was denied access to said mobile robot that said mobile robot can be accessed. 35

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88. The system of claim 87, wherein said first and second remote stations each have a class priority and said arbitrator provides robot access to said remote station with a highest priority.

89. The system of claim 88, wherein said first and second remote stations may be given said class priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot.

90. The system of claim 87, wherein said arbitrator is located within said robot.

91. A robot system, comprising:

a broadband network;

a mobile robot that is coupled to said broadband network, and has a camera and a monitor;

a first remote station that can access said mobile robot through said broadband network;

a second remote station that can access said mobile robot through said broadband network; and,

arbitration means for controlling access to said robot by said first and second remote stations, said arbitration means includes call back means for providing a message to one of said remote stations that was denied access to said mobile robot that said mobile robot can be accessed.

92. The system of claim 91, wherein said first and second remote stations each have a priority and said arbitration means provides robot access to said remote station with a highest priority. 25

93. The system of claim 92, wherein said first and second remote stations may be given priority as a local user, a doctor, a caregiver, a family member, a service user or another mobile robot. 30

94. The system of claim 91, wherein said arbitration means is located within said robot. 35

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